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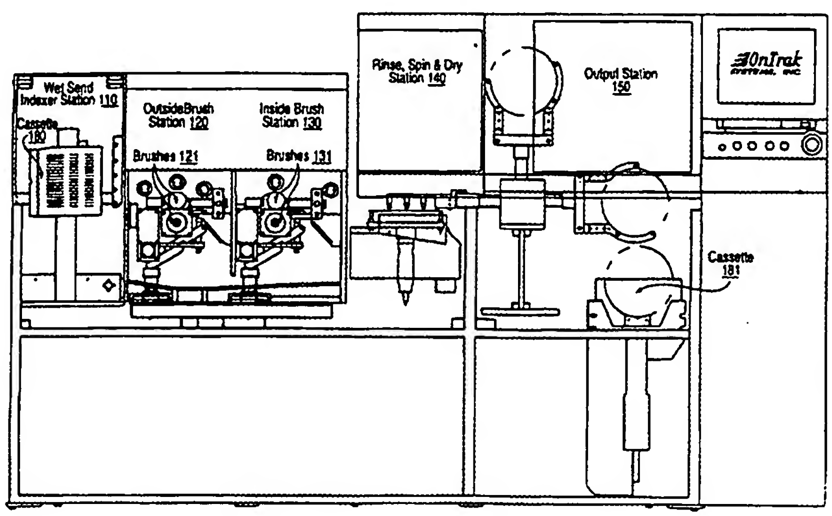
(54) Title: METHOD AND APPARATUS FOR CHEMICAL DELIVERY THROUGH THE BRUSH



(57) Abstract

A method and apparatus for chemical delivery through the brush (240) used in semiconductor substrate cleaning processes. The chemical solutions (210, 220) are delivered to the core (230) of a brush (240) where the solution is absorbed by the brush (240) and then applied by the brush (240) onto the substrate. This delivery system applies the chemical solutions (210, 220) uniformly to the semiconductor substrate, reduces the volumes of chemical solutions (210, 220) used in a scrubbing process, and helps maintain control of the pH profile of a subtrate. This system is described and illustrated in the manner it is used in conjunction with a scrubber that scrubs both sides of a semiconductor substrate.

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Method and Apparatus for Chemical Delivery Through the Brush

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to methods of processing a substrate, and more specifically, to a method and apparatus for the delivery of chemical solutions during the cleaning process of, for example, semiconductor wafers.

2. Background Information

In the manufacture of semiconductor devices, the surface of semiconductor wafers must be cleaned of wafer contaminants. If not removed, wafer contaminants may affect device performance characteristics and may cause device failure to occur at faster rates than usual.

A scrubber that scrubs a wafer on either one or both sides may be used to remove wafer contaminants. The type of cleaning solution (solution) used in the scrubber may depend upon the type of contaminants to be removed, the particular type of wafer to be scrubbed, and/or the particular manufacturer's preferred method for cleaning. For example, some manufacturers require a low level of contamination and may use a chemical solution for scrubbing, while other manufacturers have a higher contamination tolerance (i.e. less contamination need be removed) and use water for scrubbing.

As the type of solution depends upon manufacturing requirements, similarly, the method or apparatus used to deliver that solution may depend upon the manufacturer's requirements and the type of solution being used. Submersing the wafer in the solution, spraying the solution on the wafer, and dripping the solution on the wafer or the brush are examples of methods used to deliver the solution for scrubbing. The drip delivery system is described in a copending application titled "Drip Chemical Delivery Method and Apparatus," serial number 08/275,785, filed on July 15, 1994, and assigned to the assignee herein. Each of these methods have their advantages and disadvantages.

Submersing the wafer in the solution requires large volumes of chemical solutions. Some of the solutions, for example, NH_4OH, can be expensive and dangerous to use. Thus, reducing the volume of solution used is desired.

Spraying the wafer also uses large volumes of solutions. Another disadvantage to spraying is that there is very little control over the chemical composition at the wafer surface. For example, some systems and process may use relatively quick bursts of high pH solutions, such that the pH profile of the surfaces may change rapidly and may not be easily controlled. If the pH profile of the surface is not controlled damage may result to the wafer.

Dripping the solution on the wafer or brush uses smaller volumes of the solution, but may result in nonuniform delivery of the solution. Thus, only the areas of the wafer where the solution was dripped may be cleaned. Also, dripping the solution on the wafer may damage the wafer, depending upon the reactivity of the solution. Some solutions may react as soon as they hit the wafer surface and may cause "grooves" or "holes" to be formed where the solution is dripped onto the wafer. Other solutions, for example NH_4OH, do not react as quickly and do not damage the wafer.

Thus, what is needed is a method and apparatus, which may be used in existing scrubbers, that apply the solutions in a manner that allows uniform distribution of the solution and greater control over the pH profile, but that does not use large amounts of chemicals.

SUMMARY OF THE INVENTION

The present invention describes a method and apparatus used in a substrate cleaning system wherein a cleaning solution is applied to a substrate through a brush, such that the cleaning solution is distributed uniformly over the substrate surface.

Additional features and benefits of the present invention will become apparent from the detailed description, figures, and claims set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the accompanying figures in which:

Figure 1 represents a cross sectional view of a DSS-200™ system configuration.

Figure 2 illustrates a currently preferred embodiment of a high concentration chemical delivery system.

Figure 3 illustrates a currently preferred embodiment of a low concentration chemical delivery system.

DETAILED DESCRIPTION

A Method and Apparatus for Chemical Delivery Through the Brush is disclosed. In the following description, numerous specific details are set forth such as specific materials, process steps, process parameters, solutions, etc. in order to provide a thorough understanding of the present invention. It will be obvious, however, to one skilled in the art that these specific details need not be employed to practice the present invention. In other instances, well known materials or methods have not been described in detail in order to avoid unnecessarily obscuring the present invention.

The present invention may be employed in a number of substrate cleaning procedures. Although the present invention is described in conjunction with the scrubbing of a wafer, it will be appreciated that any similarly shaped, i.e. generally flat substrate, may be processed by the methods and apparati of the present invention. Further, it will be appreciated that reference to a wafer or substrate may include a bare or pure semiconductor substrate, with or without doping, a semiconductor

substrate with epitaxial layers, a semiconductor substrate incorporating one or more device layers at any stage of processing, other types of substrates incorporating one or more semiconductor layers such as substrates having semiconductor on insulator (SOI) device, or substrates for processing other apparati and devices such as flat panel displays, multichip modules, etc. However, to avoid obscuring the invention the following description will describe wafer cleaning in general and as an example of a preferred embodiment will describe the use of the present invention in a scrubbing process.

Overview of the Scrubbing Process

As an example, and not by limitation, the present invention is described in conjunction with a scrubbing process, more specifically, a scrubbing process in which both sides of the wafer are scrubbed. The scrubber includes a number of stations. Each of these stations represents one or more steps in the substrate cleaning process. Contaminated substrates are loaded at one end of the system and cleaned and dried substrates are unloaded from the other end of the system. An example of a system of this type is the DSS-200™ scrubber available from OnTrak Systems, Inc. of Milpitas, California.

Figure 1 represents a cross sectional view of a DSS-200™ configuration (cleaning system). Usually, the contaminated substrates are delivered to the cleaning system after chemical mechanical polishing (CMP), from a wet bench, or from other processes resulting in contamination. At the start of the cleaning process contaminated substrates are loaded into a wafer cassette 180 (cassette) and the cassette 180 is then placed into the wet send indexer station 110. After cassette 180 is placed into wet send indexer station 110 the substrates are automatically removed from the cassette 180 and placed, one at a time, into the outside brush station 120.

In the outside brush station 120 a substrate is processed through a first scrub. In a currently preferred embodiment, the substrate is treated with an ammonium hydroxide (NH_4OH) solution during the first scrub. The NH_4OH solution is applied to the substrate through brushes 121.

Delivery of the NH_4OH chemical solution through the brushes is discussed in detail below, following the overview of the scrub process.

The scrubbed substrate is then automatically removed from the outside brush station 120 and placed into the inside brush station 130. In the inside brush station 130, the substrate is processed through a second scrub. In a currently preferred embodiment, the substrate is treated with an hydrogen fluoride (HF) solution during the second scrub. As in the first scrub step, the HF solution is applied to the substrate through brushes 131. Delivery of the HF chemical solution through the brushes is also discussed in detail below, following the overview of the scrub process.

After the second scrub the substrate is then automatically removed from the inside brush station 130 and placed into the rinse, spin and dry station 140. Rinse, spin, and dry station 140 rinses, spins, and dries the substrate. At this point the wafer has been cleaned.

Once the rinse, spin, and dry steps have been completed the substrate is then transported from the rinse, spin, and dry station 140 to the output station 150 where the substrate will be placed into cassette 181. The transfer is usually carried out by a robotic arm which lifts the substrate out of the rinse, spin, and dry station 140 by its edges and places it into the cassette 181. The cassette is then transferred to storage or to another cleaning or processing system.

It will be clear to one of ordinary skill in the art that some of the steps in the cleaning system described above may occur in another order or with different solutions other than as presented. For example, the ammonium hydroxide and hydrogen fluoride solutions used in the brush stations 120 and 130, respectively, may be reversed. As another example, different solutions, such as water, citric acid, and ammonium citrate may be used in place of the ammonium hydroxide or hydrogen fluoride solutions.

It should be noted that while the following description illustrates the use of the present invention in a cleaning system in which both sides of the substrate are scrubbed, the present invention may be used in other

cleaning systems and processes. For example, a cleaning system in which only a single side of the substrate is scrubbed.

Chemical Solution Delivery Systems

As referred to above in the discussion of the brush stations, a chemical delivery system that applies the chemical solution to the substrate through the brushes may be employed. The particular delivery system used may depend upon what chemical solution is being used and the desired concentration of the solution. Two types of systems are described below: one where a high concentration of a chemical is delivered to the brush and then diluted and another where a lower concentration of a chemical (i.e. an already dilute chemical solution) is delivered to the brush.

The first system to be described is a chemical delivery system through a brush where a high concentration of a chemical is delivered directly to the brush and is then diluted by the delivery of water (high concentration chemical delivery system). A currently preferred embodiment of high concentration chemical delivery system is illustrated in Figure 2. As an example, the high concentration chemical delivery system is described below in conjunction with the delivery of ammonium hydroxide (NH_4OH). It will be obvious to one with ordinary skill in the art that other chemicals may be used in conjunction with the described system.

NH_4OH is used to change the zeta potential between the surface of the substrate and the contaminants. The zeta potential is related to the surface energy or "charge" at the surface of the substrate and contaminants. NH_4OH changes the zeta potential such that the contaminants and substrate surface have potentials which are of like charges and thus repel one another.

In a currently preferred embodiment of the high concentration chemical delivery system 200 there are two separate delivery tubes: one tube for delivering a chemical, for example NH_4OH, (i.e. delivery tube 210) and another tube for delivering water, for example deionized water (i.e. delivery tube 220). Providing separate delivery tubes for the

chemical, NH_4OH, and the water allows the flow rate of the NH_4OH to be controlled separately from the flow rate of the deionized water. In one currently preferred embodiment the flow rate of deionized water ranges from approximately 0.5 to 1 liter per minute, and the flow rate of NH_4OH ranges from approximately 50 to 500 milliliters per minute at concentrations in the range of approximately 0.5 to 29 percent. Because the two delivery tubes are separate the deionized water may flow constantly through the brush while scrubbing and then the NH_4OH may be turned on or off as needed to control the zeta potential of the substrate. It should be noted and it will be obvious to one with ordinary skill in the art, however, that either delivery tube may be turned on or off at any time and also that other flow rates and concentrations may be used as desired by a particular user.

Referring to Figure 2, delivery tube 210 is located inside delivery tube 220. It will be obvious to one with ordinary skill in the art that other arrangements for the setup of the delivery tubes may be used, for example, the tubes may be located side by side rather than one inside the other. In another embodiment of delivery system 200 a baffle is placed on the end of delivery tube 210 so that the NH_4OH does not shoot out of the delivery tube in a stream. It should also be noted that it will be obvious to one with ordinary skill in the art that the size of the delivery tubes may vary according to the desired concentrations, volumes, and flow rates for the particular cleaning process.

As shown in Figure 2, delivery tubes 210 and 220 deliver the NH_4OH and deionized water, respectfully, into hollow core 230 of brush 240 in delivery system 200. The NH_4OH and deionized water are mixed thoroughly in hollow core 230 so that the chemical solution may be distributed in uniform concentrations to the brush. It will be obvious to one with ordinary skill in the art that hollow core 230 may be comprised of a simple space, tubing, channels, pockets, etc.

The brush 240 may generally be selected from two types of brushes: bristle and sponge brushes. In a currently preferred embodiment of the present invention, PVA sponge brushes are used. The chemical solution (NH_4OH solution) is distributed to the brushes

such that the brushes are evenly soaked (or saturated) with the NH_4OH solution. In the currently preferred embodiment illustrated in Figure 2 the brushes are saturated with the NH_4OH solution by absorbing the solution through the slots (or holes) 250 in the outer rim of hollow core 230. It will be obvious to one with ordinary skill in the art that other implementations and devices may be used to evenly soak the brushes, for example, baffles or channels may be used.

As brush 240 is being saturated with the NH_4OH solution it is rotated by rotation device 260. Rotation device 260 turns brush 240 in a clockwise (or counterclockwise) manner, thereby applying the NH_4OH solution to the substrate while scrubbing the substrate to remove contaminants. Because brush 240 is saturated with the NH_4OH solution the solution is uniformly applied to the substrate. Uniform distribution of a chemical solution is essential to control the pH level on the substrate surface. Nonuniform distribution of the chemical solution can cause poor or reduced contamination removal in localized areas on the substrate surface.

After the substrate has been scrubbed the substrate may then be rinsed with water. In a currently preferred embodiment, the substrate is rinsed by turning off delivery tube 210 so that the flow of NH_4OH is cut off and only deionized water is being delivered into hollow core 230. After delivery tube 210 is turned off, the NH_4OH solution dissipates and gradually lowers the pH level on the surface of the substrate for the duration of the scrub. Hence, not only does the chemical delivery system 200 apply the chemical solution uniformly, but delivery system 200 also maintains control of the pH level on the substrate. It should be noted that the substrate may also be rinsed by spraying; however, rinsing with the deionized water delivery through the brush not only rinses the substrate but also rinses the remaining NH_4OH solution out of brush 240. Depending upon the type of chemical being used rinsing brush 240 may extend the useful lifetime of the brush and may also be useful in preparing the scrubbing system so that other chemicals may be substituted for the NH_4OH.

As stated above the particular delivery system used may depend upon what type of chemical solution is being used and the desired level of concentration of that solution. The second system to be described is a chemical delivery system through a brush where a low concentration of a chemical is delivered to a brush (low concentration chemical delivery system). A currently preferred embodiment of a low concentration chemical delivery system is illustrated in Figure 3. As an example, the low concentration chemical delivery system is described below in conjunction with the delivery of hydrogen fluoride (HF). It will be obvious to one with ordinary skill in the art that other chemicals may be used in conjunction with the described system.

HF is used to remove a thin layer of oxide from the substrate surface. During chemical mechanical polishing a substrate may develop microcracks in an oxide layer. In these microcracks small deposits of materials, such as potassium and sodium, build up. In order to remove these microcracks (and the material deposits that have been built up inside them) a short etch to remove a thin coating of the oxide layer is performed. Scrubbing the substrate with an HF solution is one method of performing such an etch. The substrate is scrubbed in an HF solution until approximately 25Å to approximately 250Å of the oxide layer is removed, thus removing the materials deposited in the microcracks. In one currently preferred embodiment the substrate is scrubbed in an HF solution until approximately 100Å of the oxide layer is removed.

Because HF reacts very quickly with the substrate surface it is preferable to use an HF solution with a lower concentration, but in high volumes. An HF solution with a concentration in the range of approximately 0.25 percent to approximately 2 percent may be applied to the substrate. In one currently preferred embodiment an HF solution with a concentration of approximately 100:1 H_2O:HF.

In a currently preferred embodiment of the low concentration chemical delivery system 300, the premixed HF solution and water are sequentially supplied through supply lines 310 and 320, respectively. Also in the currently preferred embodiment described above, supply line 320 supplies the necessary amounts of water, for example deionized

water, to the brush in order to keep the brush and substrate moist during the scrubbing process. When it is desired to perform the etch, supply line 320, which delivers water, is turned off and supply line 310, which delivers the HF solution, is turned on. After a predetermined amount of time or after a satisfactory etch has been performed, HF supply line 310 is turned off and water supply line 320 is turned back on.

Supply lines 310 and 320 run into delivery tube 370. Delivery tube 370 then delivers the HF solution or the deionized water into hollow core 330 of brush 340 at a predetermined flow rate. The flow rate for HF may be in the range of approximately 0.2 to approximately 0.7 liters per minute and the flow rate for deionized water may be in the range of approximately 0.5 to approximately 1 liter per minute. It will be obvious to one with ordinary skill in the art that other arrangements may be used to supply the HF solution and deionized water, for example, the delivery tubes 210 and 220 as described with respect to the high concentration chemical delivery system above may be used, provided the specific flow rates for each chemical or solution are set appropriately, etc.

As with the high concentration chemical delivery system described above, the brush 340 of the low concentration chemical delivery system may generally be selected from two types of brushes: bristle and sponge brushes. In a currently preferred embodiment of the present invention, PVA sponge brushes are used. During the etch, the chemical solution (HF solution) is distributed to the brushes such that the brushes are evenly soaked (or saturated) with the HF solution. In the currently preferred embodiment illustrated in Figure 3 the brushes are saturated with the HF solution by absorbing the solution through the slots (or holes) 350 in the outer rim of hollow core 330. It will be obvious to one with ordinary skill in the art that other implementations and devices may be used to evenly soak the brushes, for example, baffles or channels may be used.

As brush 340 is being saturated with the HF solution it is rotated by rotation device 360. Rotation device 360 turns brush 340 in a clockwise (or counterclockwise) manner, thereby applying the HF solution to the substrate. Because brush 340 is saturated with the HF solution, the

solution is uniformly applied to the substrate. Thus, the substrate is uniformly etched to remove the contaminant filled microcracks of the oxide layer.

The HF solution is only applied until the desired amount of the oxide layer is removed, for example, in the above mentioned preferred embodiment until approximately 100Å is removed. Once the desired level is reached the etch must be stopped. To stop the etch HF supply line 310 is turned off and water supply line 320 is turned back on. After supply line 310 is turned off, the HF solution dissipates and the brush and substrate are rinsed with only deionized water, thus stopping the etch.

It should be noted and it will be obvious to one with ordinary skill in the art, that other methods for rinsing the brush and substrate, for example spraying with deionized water, are also available. It should also be noted that although the present invention is described above with respect to NH_4OH and HF solutions, the present invention may also be practiced with other chemical solutions, for example, citric acid, ammonium citrate, hydrogen chloride, chelating agents, surfactants, chemical mixtures, etc. Additionally, it will be obvious to one with ordinary skill in the art that the low concentration and high concentration delivery systems may be used in either brush station one or brush station two or the same delivery system may be used in both brush stations.

The above described chemical delivery systems (i.e. chemical delivery through the brush) apply chemical solutions in a uniform manner to the semiconductor substrate, reduce the volumes of chemical solutions used in a scrubbing process, and help maintain control of the pH profile of a substrate during scrubbing.

Thus, a Method and Apparatus for Chemical Delivery Through the Brush has been described. Although specific embodiments, including specific equipment, process steps, process parameters, materials, solutions, and etc. have been described, various modifications to the disclosed embodiments will be apparent to one of ordinary skill in the art upon reading this disclosure. Therefore, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad

invention and that this invention is not limited to the specific embodiments shown and described.

CLAIMS

What is claimed is:

1. A method of cleaning a substrate comprising:
providing said substrate;
applying a solution to said substrate through a brush; and
scrubbing said substrate with said brush.

2. The method as described in claim 1 wherein said solution is applied for a predetermined amount of time.

3. The method as described in claim 1 further comprising a step of:
rinsing said brush for a predetermined amount of time after said step of scrubbing said substrate.

4. A method for removing contaminants from a substrate comprising:
providing a substrate;
scrubbing said substrate with a brush;
applying a solution to said substrate, wherein said solution comprises HF; and
rinsing said brush.

5. The method as described in claim 4 wherein said solution is applied during said scrubbing step through said brush.

6. The method as described in claim 4 wherein said scrubbing step continues until approximately 100 Å of an oxide layer on said substrate is removed.

7. A method for removing contaminants from a substrate comprising:
providing a substrate;
placing said substrate in a scrubber;
performing a first scrubbing cycle in a first brush station, wherein a first solution is applied to said substrate through a first brush;

performing a second scrubbing cycle in a second brush station, wherein a second solution is applied to said substrate through a second brush; and

rinsing said substrate.

8. The method as described in claim 7 wherein said first scrubbing cycle comprises:

scrubbing said substrate with said first brush;

applying said first solution to said substrate, wherein said first solution comprises NH_4OH; and

rinsing said first brush.

9. The method as described in claim 7 wherein said second scrubbing cycle comprises:

scrubbing said substrate with said second brush;

applying said second solution to said substrate, wherein said second solution comprises HF; and

rinsing said second brush.

10. An apparatus for a brush assembly comprising:

a brush, wherein said brush has a core, said core having a space therein;

a rotation device, wherein said rotation device rotates said brush; and

a solution delivery system, said solution delivery system disposed to deliver a solution to said space in said core.

11. The apparatus as described in claim 10 wherein said brush is a PVA brush.

12. The apparatus as described in claim 10 wherein said solution delivery system comprises:

a first delivery tube, wherein said first delivery tube delivers a first solution at a first flow rate;

a second delivery tube, wherein said second delivery tube delivers a second solution at a second flow rate;

a first device for controlling the first flow rate of said first delivery tube; and

a second device for controlling the second flow rate of said second delivery tube.

13. The apparatus as described in claim 12 wherein said first solution is NH_4OH and said second solution is deionized water.

14. The apparatus as described in claim 12 wherein said first delivery tube is located inside said second delivery tube.

15. The apparatus as described in claim 10 wherein said solution delivery system comprises:

a first supply line, wherein said first supply line supplies a first solution;

a second supply line, wherein said second supply line supplies a second solution;

a delivery tube, wherein said first supply line and said second supply line are connected to said delivery tube; and

a device for controlling the flow rate of said delivery tube.

16. The apparatus as described in claim 15 wherein said first solution is HF and said second solution is deionized water.

17. An apparatus for a brush assembly comprising:

a brush, wherein said brush is a PVA brush with a hollow core;

a rotation device, wherein said rotation device rotates said brush;

a solution delivery system, wherein said solution delivery system places a solution inside said hollow core of said brush.

18. The apparatus as described in claim 17 wherein said solution delivery system comprises:

a first delivery tube, wherein said first delivery tube delivers a first solution at a first flow rate;

a second delivery tube, wherein said second delivery tube delivers a second solution at a second flow rate;

a first device for controlling the first flow rate of said first delivery tube; and

a second device for controlling the second flow rate of said second delivery tube.

19. The apparatus as described in claim 18 wherein said first solution is NH_4OH and said second solution is deionized water.

20. The apparatus as described in claim 18 wherein said first delivery tube is located inside said second delivery tube.

21. The apparatus as described in claim 17 wherein said solution delivery system comprises:

a first supply line, wherein said first supply line supplies a first solution;

a second supply line, wherein said second supply line supplies a second solution;

a delivery tube, wherein said first supply line and said second supply line are connected to said delivery tube; and

a device for controlling the flow rate of said delivery tube.

22. The apparatus as described in claim 21 wherein said first solution is HF and said second solution is deionized water.

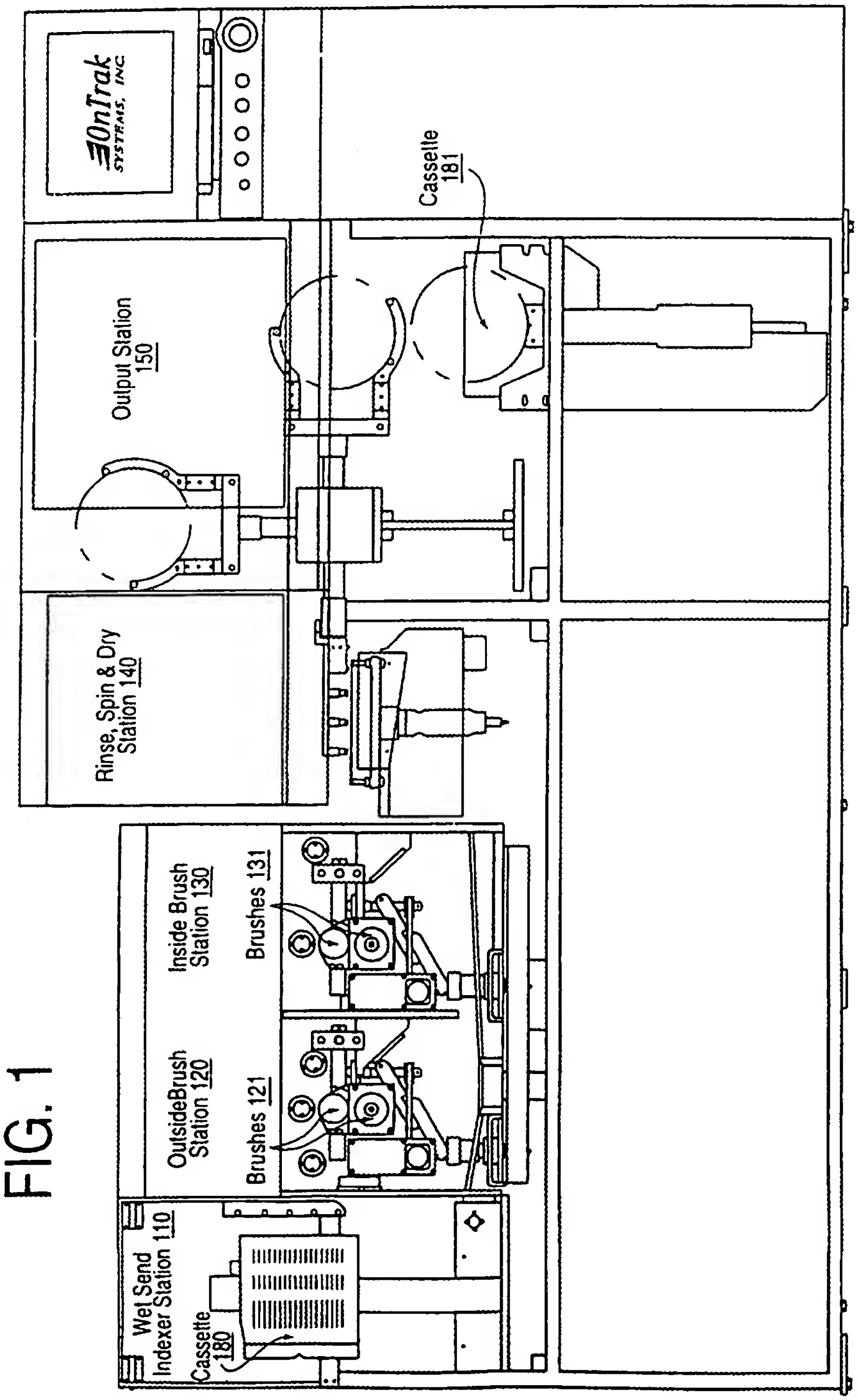
OnTrak SYSTEMS, INC
Cassette 181
Output Station 150
Rinse, Spin & Dry Station 140
Inside Brush Station 130
Brushes 131
OutsideBrush Station 120
Brushes 121
Wet Send Indexer Station 110
Cassette 180

FIG. 1

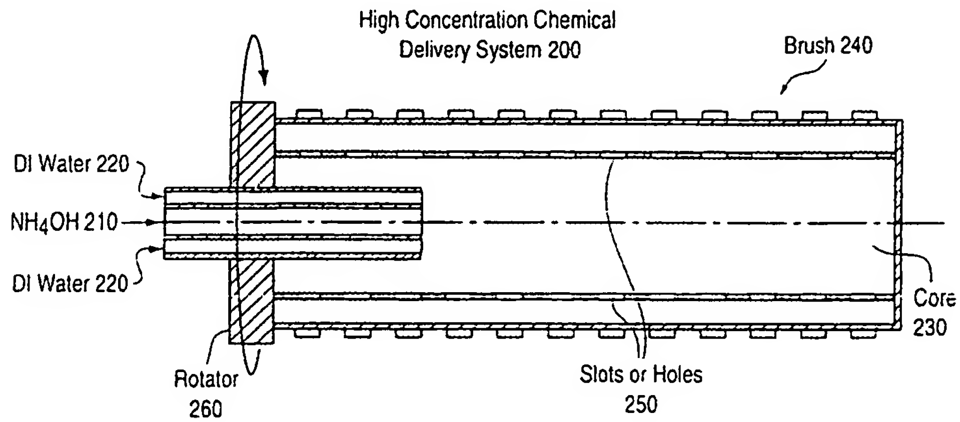
High Concentration Chemical Delivery System 200
Brush 240
DI Water 220
NH4OH 210
DI Water 220
Core 230
Rotator 260
Slots or Holes 250

FIG. 2

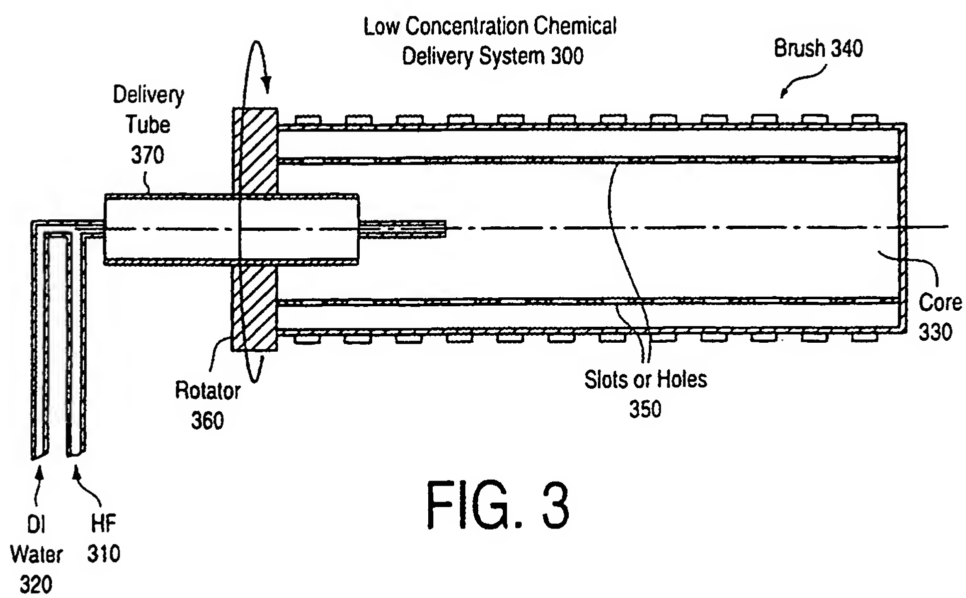
Low Concentration Chemical Delivery System 300
Brush 340
Delivery Tube 370
Core 330
Rotator 360
Slots or Holes 350
DI Water 320
HF 310

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/16330

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B08B 1/00, 3//08; C23G 1/00, 1/02, 1/14; A46B 11/00, AND 13/00
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 134/6, 7, 2, 3, 26, 28, 29; 15/21.1, 77, 88.2, 88.3, 88.4, 97.1, and 102

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SEMICON KOREA 95, PROCESS TECHNOLOGY, Semiconductor Equipment and Materials International, 19 January 1995, "Post-CMP Cleaning Technology", page 29-36.	1-22
Y	US,A, 4,461,052 (MOSTUL) 24 July 1984, See the abstract, Figure 1, and the document in general.	1-22
Y	US,A, 3,500,490 (TEREN) 17 March 1970. See cols. 1-4 and the claims.	10-22
A	US,A, 2,860,354 (VAN CLIEF, JR) 18 November 1958. See col. 3.	10-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 DECEMBER 1996	13 JAN 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Nicholas Thomas ZEINAB EL-ARINI
Facsimile No. (703) 305-3230	Telephone No. (703) 308-3320

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/16330

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

134/6, 7, 2, 3, 26, 28, 29; 15/21.1, 77, 88.2, 88.3, 88.4, 97.1, and 102

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/16330

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I, claims 1-9 are drawn to a method of cleaning a substrate, classified in class 134, subclass 6.

Group II, claims 10-22 are drawn to apparatus for a brush assembly, classified in class 15, subclass 77.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.